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PATENT ABSTRACTS OF JAPAN

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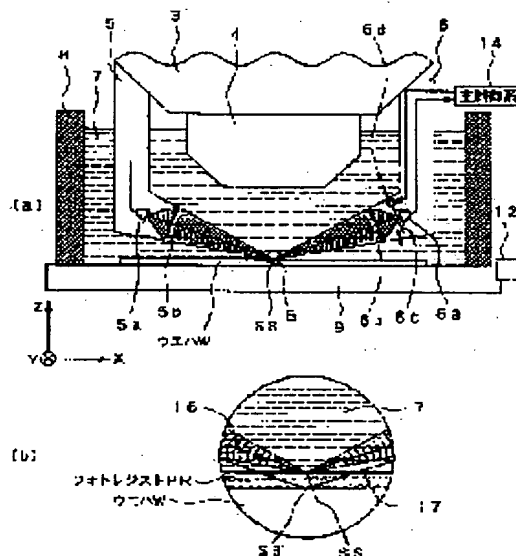
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(54) PROJECTION ALIGNER

(57)Abstract:

PROBLEM TO BE SOLVED: To detect with high precision a position in an optical axis direction of a projection optical system on a surface of a substrate, even when wavelengths of aligned lights are substantially reduced and moreover the alignment is carried out in a liquid.

SOLUTION: A liquid 7 is supplied to a sidewall 8 so as to satisfy a gap between a lens 4 of a projection optical system which is closest to a wafer W and the wafer W. Ultrasonic waves are emitted from an ultrasonic emission system 5, and the ultrasonic waves reflected by an ultrasonic focusing position SS are received by an ultrasonic reception system 6. Based on a detection signal from the ultrasonic reception system 6, a defocusing amount from a best focusing position in a focusing position SS of ultrasonic waves is acquired. Based on the acquired defocusing amount, a sample ore pedestal 9 is driven in a Z-direction to control a focusing position.



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CLAIMS

[Claim(s)]

[Claim 1] The projection aligner characterized by to have field location detection equipment of the ultrasonic sensing method which detects the location of the direction of an optical axis of said projection optics of said front face by detecting the supersonic wave which sends out a supersonic wave to the immersion equipment which supplies a predetermined liquid to the front face of said substrate, and the front face of said substrate through said liquid in the projection aligner which imprints a mask pattern on a substrate through projection optics, and is reflected on said front face.

[Claim 2] It is the projection aligner according to claim 1 characterized by said field location detection equipment detecting the location of the direction of an optical axis of said projection optics of the front face of said sensitive material when sensitive material is applied to the front face of said substrate.

[Claim 3] Claim 1 characterized by supplying said liquid so that between the point of the optical element by the side of said substrate of said projection optics and the front faces of said substrate may be filled, or a projection aligner given in two.

[Claim 4] Said liquid is a projection aligner claims 1 and 2 characterized by being water or an organic solvent, or given in three.

[Claim 5] The projection aligner of claim 1-4 characterized by having the substrate stage which holds said substrate and positions this substrate on a flat surface perpendicular to the optical axis of said projection optics, and the height control stage which controls the location of the direction of an optical axis of said projection optics of said substrate based on the detection result of said field location detection equipment given in any 1 term.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the projection aligner used for the lithography process for manufacturing a semiconductor device, a liquid crystal display component, or the thin film magnetic head.

[0002]

[Description of the Prior Art] In case a semiconductor device etc. is manufactured, projection aligners, such as a stepper mold imprinted to each shot field on the wafers (or glass plate etc.) with which the image of the pattern of the reticle as a photo mask was applied to the resist as a substrate through projection optics or step -, and - scanning method, are used.

[0003] The resolution of the projection optics with which the projection aligner is equipped becomes so high that the exposure wavelength to be used is short and the numerical aperture of projection optics is large. Therefore, exposure wavelength used with a projection aligner with detailed-izing of an integrated circuit is short-wavelength-ized every year, and the numerical aperture of projection optics has also been increasing. And although the exposure wavelength of the current mainstream is 248nm of KrF excimer laser, 193nm use of the ArF excimer laser of short wavelength is also considered further.

[0004] Moreover, in case it exposes, the depth of focus as well as resolution becomes important. Resolution R and the depth of focus delta are expressed with the following formulas, respectively.

$R = k1 \text{ and } \lambda/NA$ (1)

$\Delta = k2 \text{ and } \lambda/NA^2$ (2)

Here, λ is exposure wavelength and NA is the numerical aperture of projection optics, $k1$, and $k2$. It is a process multiplier. When obtaining the same resolution, the depth of focus with bigger using the exposure light of short wavelength can be obtained. however, the spectrum of the penetrable optical member (** material) used for projection optics -- if a transparency property is taken into consideration, while being able to penetrate the exposure light of the wavelength of ArF excimer laser shorter than 193nm at present, there is almost no uniform ** material which can form a comparatively big lens.

[0005]

[Problem(s) to be Solved by the Invention] It is difficult like the above to use the exposure light of the wavelength of ArF excimer laser shorter than 193nm in the conventional projection aligner (projection optics). Then, it considers as the approach of shortening exposure wavelength substantially, and the immersion method is proposed. A wafer is dipped into a predetermined liquid, and this improves resolution using the wavelength of the exposure light in the inside of a liquid increasing $1/n$ time in air (n being usually 1.2 to about 1.6 at the refractive index of a liquid), and increases the depth of focus.

[0006] By the way, since the whole exposure range needs to enter within the limits of the depth of focus of projection optics at the time of exposure, the focus device (automatic focus device) is prepared in the projection aligner. Incidence of the light beam is carried out to the front face of the wafer which should generally be exposed by oblique incidence, the reflected light is received by the optical system of a confrontation, the focus condition on the front face of a wafer is detected, and this moves a wafer up and down, and drives in to a focus location.

[0007] The film (photoresist) is applied to the wafer front face exposed, and a pattern is imprinted by this photoresist. Then, it is desirable to make this photoresist front face in agreement with the focal location of projection optics, and it needs to detect ***** on the front face of a photoresist. The space where a wafer is arranged is filled with the conventional projection aligner with gases, such as air or nitrogen. And the refractive index of air is 1, for example, and the refractive index of the photoresist applied to the wafer front face is about 1.7. Therefore, the reflection factor of the light in an air-photoresist interface is calculated as follows than Fresnel's formulas.

Reflection factor = $\{(1-1.7)/(1+1.7)\} \times 100 = 6.7 (\%)$ (3)

an air-photoresist interface -- the flux of light for focus detection -- many reflect comparatively and the location on the front face of a photoresist can be detected.

[0008] However, the space where a wafer is arranged will be filled with a liquid at the case of the projection aligner which adopted the immersion method. For example, when a liquid is water, the refractive index is 1.3 and the reflection factor of the light in a water-photoresist interface is calculated as follows than Fresnel's formulas.

Reflection factor = $\{(1.3-1.7)/(1.3+1.7)\} \times 100 = 1.8 (\%)$ (4)

In a water-photoresist interface, since the difference of the refractive index of space and a photoresist becomes remarkably small compared with an air-photoresist interface, the reflection factor of the flux of light for focus detection falls, and it becomes difficult to detect the location on the front face of a photoresist correctly.

[0009] This invention short-wavelength-izes wavelength of exposure light in view of this point, and it aims at offering the projection aligner which can imprint a more detailed pattern. Furthermore, even if it is the case where exposure is performed on the substrate with which sensitive material was applied in the liquid, it aims also at offering the projection aligner which can detect the location of the direction of an optical axis of the projection optics of the front face of the sensitive material with high precision.

[0010]

[Means for Solving the Problem] In the projection aligner with which the projection aligner of this invention imprints the pattern image of a mask (R) on a substrate (W) through projection optics (PL) The immersion equipment which supplies a predetermined liquid (7) to the front face of the substrate (W) (2 8), A supersonic wave is sent out to the front face of the substrate (W) through a liquid (7), and it has field location detection equipment (5 6) of the ultrasonic sensing method which detects the location of the direction of an optical axis of the projection optics (PL) of the front face by detecting the supersonic wave reflected on the front face.

[0011] According to the projection aligner of this this invention, since the pattern image of a mask (R) is exposed on the surface of a substrate (W) through a liquid (7),-izing of the wavelength of the exposure light in a substrate front face can be carried out [short wavelength] $1/n$ time (n is the refractive index of a liquid (7)) of the wavelength in air. Moreover, since the field location detection equipment (5 6) of an ultrasonic sensing method detects the location of the direction of an optical axis of the front face of a substrate (W) with high precision, with optical field location detection equipment, detection of a field location can detect the location with high precision in a difficult liquid (7).

[0012] Moreover, when sensitive material (PR) is applied on the surface of the substrate (W), as for field location detection equipment (5 6), it is desirable to detect the location of the direction of an optical axis of the projection optics (3 4) of the front face of the sensitive material (PR). In this case, the image surface of projection optics (3 4) can be doubled with the front face of that sensitive material (PR). Moreover, it is desirable to supply a liquid (7) so that between the points and the front faces of a substrate (W) of the optical element (4) by the side of the substrate (W) of projection optics (PL) may be filled. In this case,-izing of the wavelength of the exposure light in a substrate (W) front face can be carried out [short wavelength] $1/n$ time (n is the refractive index of a liquid (7)) of the wavelength of the exposure light in air. Furthermore, in order that the lens-barrel (3) of projection optics (PL) may not contact a liquid (7), there is an advantage of being hard coming to corrode a lens-barrel (3).

[0013] Moreover, the liquid (7) is water (refractive index 1.3) or organic solvents (for example, alcohol (ethanol (refractive index 1.36) etc.), cedar oil (refractive index 1.52), etc.). In this case, in

using water as a liquid (7), there is an advantage that that acquisition is easy. Moreover, in using an organic solvent as a liquid (7), there is an advantage of being hard coming to corrode the lens-barrel (3) of projection optics (PL). Furthermore, when using cedar oil as a liquid (7), the refractive index is as large as about 1.5, and can short-wavelength-ize exposure light more.

[0014] Moreover, it is desirable to have the substrate stage (10) which holds a substrate (W) and positions this substrate (W) on a flat surface perpendicular to the optical axis of projection optics (PL), and the height control stage (9) which controls the location of the direction of an optical axis (3 4) of the projection optics of that substrate (W) based on the detection result of field location detection equipment (5 6). In this case, the front face of a substrate (W) can be doubled with high precision to the image surface of projection optics (3 4).

[0015]

[Embodiment of the Invention] Hereafter, with reference to drawing 1 - drawing 3, it explains per example of the gestalt of operation of this invention. Drawing 1 (a) shows the outline configuration of the projection aligner of this example, and the exposure light IL which consists of ultraviolet pulsed light with a wavelength of 193nm injected from the illumination-light study system 1 containing the ArF excimer laser as the exposure light source, an optical integrator, a field diaphragm, a condensing lens, etc. illuminates the pattern prepared in Reticle R in this drawing 1 (a). the pattern of Reticle R -- a both-sides (or wafer side one side) tele cent -- contraction projection is carried out to the exposure field on the wafer W with which Photoresist PR was applied through the rucksack projection optics PL for the predetermined projection scale factor beta (beta is 1/4, and 1 / 5 grades). In addition, as an exposure light IL, KrF excimer laser light (wavelength of 248nm), F2 excimer-laser light (wavelength of 157nm), i line (wavelength of 365nm) of a mercury lamp, etc. may be used. The Z-axis is taken in parallel with the optical axis AX of projection optics PL hereafter, a Y-axis is taken along a direction perpendicular to the space of drawing 1 (a) in a flat surface perpendicular to the Z-axis, and the X-axis is taken and explained along a direction parallel to space.

[0016] Reticle R is held on a reticle stage RST, and the device which can be moved slightly to the direction of X, the direction of Y, and a hand of cut is included in the reticle stage RST. The two-dimensional location of a reticle stage RST and the angle of rotation are measured by real time with the laser interferometer (un-illustrating). On the other hand, Wafer W is held on the sample base 9 through a wafer holder (un-illustrating), and the sample base 9 is being fixed on Z stage 10 which controls the focal location (location of a Z direction) and tilt angle of Wafer W. On the sample base 9, the cylinder-like side attachment wall 8 is established, and gets down, and the interior is filled with the liquid 7. A liquid 7 is supplied in a side attachment wall 8 before exposure through nozzle 2a by the liquid supply recovery system 2 which consists of a pump etc., and are collected after exposure. In addition, in the projection aligner of this example, since water (refractive index 1.3) is used as a liquid 7 and the wavelength of light increases 1/1.3 time in air in underwater, wavelength of exposure light which consists of ArF excimer laser (wavelength of 193nm) is substantially short-wavelength-ized by about 148nm.

[0017] Moreover, the lens-barrel 3 of projection optics PL is metal, and it is using the contact part of projection optics PL and a liquid 7 only as the lens 4 nearest to Wafer W in this example in order to prevent corrosion with a liquid 7. Moreover, the focal location detection system (it is called "the AF sensors 5 and 6" below) which consists of an ultrasonic injection system 5 and an ultrasonic receiving system 6 is attached in the side face of the lens-barrel 3 of projection optics PL.

[0018] Drawing 1 (b) is an about eight side attachment wall [of drawing 1 (a)] enlarged drawing, and door 8a which can be opened and closed and which is used in the case of taking out from conveyance of a up to [the sample base 9 of Wafer W] or the sample base 9 is prepared in the side attachment wall 8 in this drawing 1 (b). Moreover, nozzle 2a of the liquid supply recovery system 2 has supply of a liquid, and composition which can be driven up and down in the case of recovery.

[0019] Return and Z stage 10 are fixed by drawing 1 (a) on X-Y stage 11 which moves along XY flat surface parallel to the image surface of projection optics PL, and X-Y stage 11 is laid on the non-illustrated base. Z stage 10 controls the focal location (location of a Z direction) of Wafer W, and a tilt angle, and doubles the photoresist PR front face on Wafer W with the image surface of projection optics PL by the automatic focus method and the auto leveling method, and X-Y stage 11 performs

alignment of the direction of X of Wafer W, and the direction of Y. The two-dimensional location of the sample base 9 (wafer W) and the angle of rotation are measured by real time with the laser interferometer 13 as a location of the migration mirror 12. Based on this measurement result, control information is sent to the wafer stage drive system 15 from the main control system 14, actuation of Z stage 10 and X-Y stage 11 is controlled, each shot field on Wafer W moves to a sequential exposure location at the time of exposure, and the exposure imprint of the pattern of Reticle R is carried out to each shot field.

[0020] Next, the AF sensors 5 and 6 of the projection aligner of this example are explained. Drawing 2 (a) expands and shows near the lower part of the projection optics of this example, and ultrasonic generating component 5a and focussing-of-ultrasonic-waves component 5b are prepared in the ultrasonic injection system 5 in this drawing 2 (a). It converges on the focusing location SS on the photoresist PR front face applied to Wafer W by focussing-of-ultrasonic-waves component 5b, it reflects in the focusing location SS, and incidence of the supersonic wave with a frequency of 50MHz - about 200MHz injected from ultrasonic generating component 5a which consists of a piezoelectric device etc. is carried out to the ultrasonic receiving system 6. Ultrasonic receiving component 6a, focussing-of-ultrasonic-waves component 6b, and noise insulation plate 6c that can vibrate are prepared in the ultrasonic receiving system 6, and the supersonic wave which carried out incidence to the ultrasonic receiving system 6 converges by focussing-of-ultrasonic-waves component 6b, and carries out incidence to ultrasonic receiving component 6a through opening of noise insulation plate 6c. The detecting signal of ultrasonic receiving component 6a is supplied to the main control system 14. In addition, opening which passes a supersonic wave is prepared in the center section of noise insulation plate 6c, and the location where the main control system 14 carries out the horizontal shift (or vibration) of the noise insulation plate 6c by 6d of noise insulation plate drives, and the detecting signal of ultrasonic receiving component 6a becomes max is detected. Or the synchronous detection of the detecting signal of ultrasonic receiving component 6a may be carried out by the signal which synchronized with vibrating noise insulation plate 6c.

[0021] Drawing 2 (b) expands and shows near focusing location SS of the supersonic wave on a photoresist PR front face, and the photoresist PR for sensitization is applied on Wafer W in this drawing 2 (b). In order that AF sensor of an oblique incidence method detects the location SS on a photoresist PR front face by optical [conventional], the refractive index of the liquid 7 and Photoresist PR also as a way may be comparable, a reflection factor may become very low and light may go to the front face of Wafer W in accordance with a path 17, location SS' detected is not located on the front face of Photoresist PR, but is doubled with the image surface of projection optics PL in the front face of the substrate of Wafer W itself. Since it progresses in accordance with a path 16 and is reflected on the front face of Photoresist PR, the location SS on a photoresist PR front face is detected correctly, and the supersonic wave of the AF sensors 5 and 6 of this example can make a photoresist PR front face focus to the image surface with high precision.

[0022] Moreover, the location of the Z direction of a photoresist PR front face is detected by optical [conventional] by the same principle as AF sensor of an oblique incidence method from the horizontal shift amount of the focusing location of the supersonic wave on ultrasonic receiving component 6a. That is, if the focusing location on ultrasonic receiving component 6a of drawing 2 (a) will shift up if Wafer W shifts down [in drawing 2 R > 2 (b)] (- Z direction), and Wafer W shifts above [in drawing 2 (b)], since the focusing location on ultrasonic receiving component 6a shifts caudad, it can calculate the variation of the focal location of the front face of Photoresist PR from this horizontal shift amount. Therefore, beforehand, the best focus location is defined with the test print etc., and should just double the core (or oscillating core) of opening of noise insulation plate 6c, and the core of the focusing location of a supersonic wave then.

[0023] Drawing 3 shows relation with the focal location Z of the focal signal D and a photoresist PR front face obtained by carrying out the synchronous detection of the detecting signal from the ultrasonic receiving system 6 as an example. Within the main control system 14, the focal signal D which changes in proportion [almost] to the focal location Z in the predetermined range is generated corresponding to the focusing location SS of the supersonic wave in a photoresist PR front face by detecting synchronously the detecting signal from ultrasonic receiving set 6a with the driving signal of noise insulation plate 6c. In this example, when the focusing location SS has agreed in the

image surface (best focus location) of projection optics PL, the calibration is performed so that it may be set to 0, and as for the main control system 14, the focal signal D corresponding to the focusing location SS of a supersonic wave can calculate the amount of defocusing (the amount of gaps) from the focal signal D. When the focal location of Wafer W is up, Z stage 10 (wafer W) is moved caudad, and when there is a focal location caudad conversely, it will expose by moving Z stage 10 (wafer W) up.

[0024] In addition, although water (refractive index 1.3) was used as a liquid 7 in this example, organic solvents (for example, alcohol, cedar oil, etc.) can also be used as a liquid 7. In this case, there is an advantage of being hard coming to corrode the lens-barrel 3 of projection optics PL. Moreover, when using cedar oil (refractive index 1.5), the refractive index is as large as 1.5, and can short-wavelength-ize exposure light more substantially.

[0025] In addition, the noise insulation plate which has two or more openings in the ultrasonic injection system 5 about detection of a focal location is arranged. You may make it detect each focal location of the two or more on the front face of a photoresist. Or the noise insulation plate which arranges the noise insulation plate which has big opening in the ultrasonic injection system 5, and has two or more openings is arranged in the ultrasonic receiving system 6, and you may make it detect each focal location in two or more points similarly.

[0026] In addition, with the gestalt of the above-mentioned operation, although the focal location on the front face of a photoresist of a wafer was detected using the supersonic wave, the leveling sensor which detects the tilt angle on the front face of a photoresist using a supersonic wave may be used. What is necessary is to irradiate the supersonic wave which progresses almost in parallel on the surface of a wafer, and just to detect the sound-collecting location of the supersonic wave reflected by this leveling sensor.

[0027] In addition, of course, configurations various in the range which this invention is not limited to the gestalt of above-mentioned operation, and does not deviate from the summary of this invention can be taken.

[0028]

[Effect of the Invention] According to the projection aligner of this invention, since the pattern image of a mask is exposed on the surface of a substrate through a liquid, -izing of the wavelength of the exposure light in a substrate front face can be substantially made [short wavelength] twice [inverse number] the refractive index of the liquid of the wavelength in air. Moreover, since the field location detection equipment of an ultrasonic sensing method detects the location of the direction of an optical axis on the front face of a substrate, with optical field location detection equipment, detection of a field location can detect the location with high precision in a difficult liquid.

[0029] Moreover, when field location detection equipment detects the location of the direction of an optical axis of the projection optics of the front face of sensitive material, based on the detection information, the front face of the sensitive material can be doubled with high precision to the image surface of projection optics. Moreover, when a liquid is supplied so that between the points and the front faces of a substrate of the optical element by the side of the substrate of projection optics may be filled, -izing of the exposure light can be carried out [short wavelength] $1/n$ time in air (n is the refractive index of a liquid), and in order that the lens-barrel of projection optics may not contact a liquid, there is an advantage of being hard coming to corrode the lens-barrel of projection optics.

[0030] Moreover, when a liquid is water, there is an advantage that the acquisition is easy. When liquids are organic solvents (for example, alcohol, cedar oil, etc.), there is an advantage of being hard to corrode the lens-barrel of projection optics. Furthermore, when using cedar oil as a liquid, the refractive index is large compared with 1.5, water (refractive index 1.3), etc., and exposure light can be short-wavelength-ized more.

[0031] Moreover, when it has the substrate stage which holds a substrate and positions this substrate on a flat surface perpendicular to the optical axis of projection optics, and the height control stage which controls the location of the direction of an optical axis of the projection optics of that substrate based on the detection result of field location detection equipment, the image surface of projection optics can be doubled with the exposure location on a substrate front face.

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] The outline block diagram in which (a) shows the projection aligner of an example of the gestalt of operation of this invention, and (b) are the enlarged drawings showing about eight side attachment wall of drawing 1 (a).

[Drawing 2] The partial enlarged drawing in which (a) shows the configuration of the projection aligner lower part of drawing 1 (a), and (b) are the enlarged drawings of the B section of drawing 2 (a).

[Drawing 3] It is drawing showing the focal location Z on the front face of a photoresist on Wafer W, and relation with the focal signal D.

[Description of Notations]

W Wafer

R Reticle

PL Projection optics

1 Illumination-Light Study System

2 Liquid Supply Recovery System

3 Lens-barrel

4 Lens

5 Ultrasonic Injection System

6 Ultrasonic Receiving System

7 Liquid

8 Side Attachment Wall

9 Sample Base

10 Z Stage

14 Main Control System

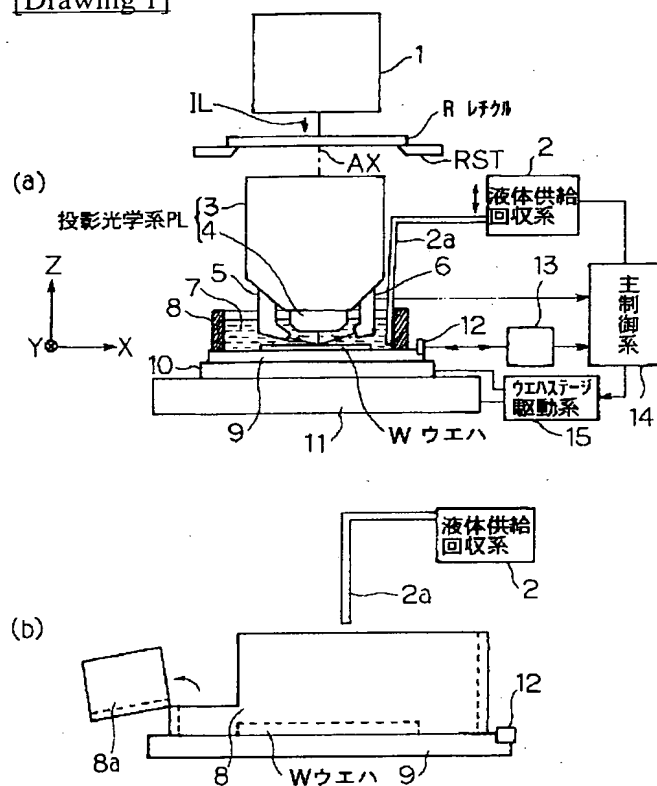
15 Wafer Stage Drive System

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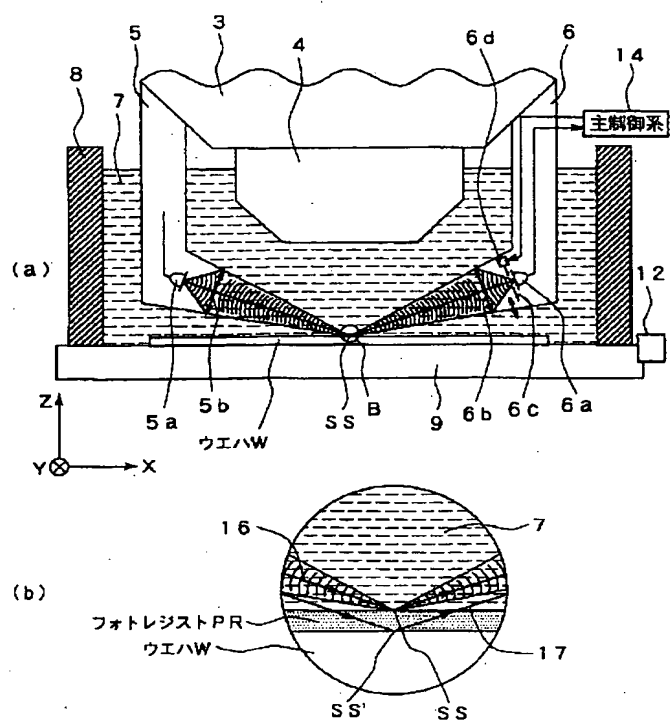
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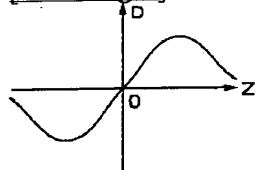
[Drawing 1]



[Drawing 2]



[Drawing 3]



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(19)



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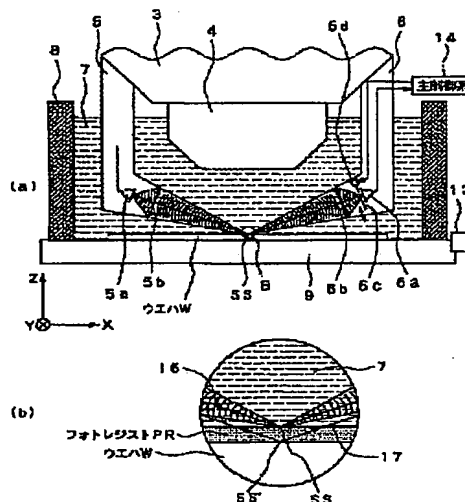
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PROBLEM TO BE SOLVED: To detect with high precision a position in an optical axis direction of a projection optical system on a surface of a substrate, even when wavelengths of aligned lights are substantially reduced and moreover the alignment is carried out in a liquid.

SOLUTION: A liquid 7 is supplied to a sidewall 8 so as to satisfy a gap between a lens 4 of a projection optical system which is closest to a wafer W and the wafer W. Ultrasonic waves are emitted from an ultrasonic emission system 5, and the ultrasonic waves reflected by an ultrasonic focusing position SS are received by an ultrasonic reception system 6. Based on a detection signal from the ultrasonic reception system 6, a defocusing amount from a best focusing position in a focusing position SS of ultrasonic waves is acquired. Based on the acquired defocusing amount, a sample or pedestal 9 is driven in a Z-direction to control a focusing position.

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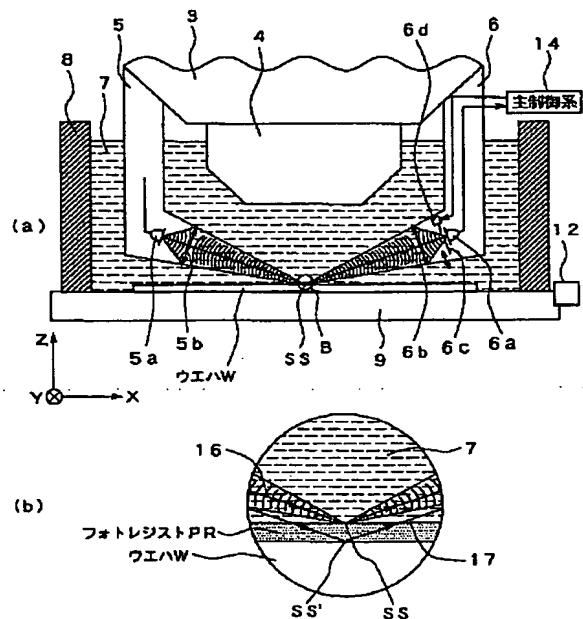
(74) 代理人 弁理士 大森 聡

(54) 【発明の名称】 投影露光装置

(57) 【要約】

【課題】 露光光を実質的に短波長化し、また、露光が液体中で行われる場合であっても、基板表面の投影光学系の光軸方向の位置を高精度に検出する。

【解決手段】 ウエハWに最も近い投影光学系のレンズ4とウエハWとの間を満たすように側壁8内に液体7を供給する。超音波射出系5から超音波を射出し、超音波集束位置SSにおいて反射した超音波を超音波受信系6により受信する。超音波受信系6からの検出信号に基づいて、超音波の集束位置SSにおけるベストフォーカス位置からのデフォーカス量を求める。求められたデフォーカス量に基づいて試料台9をZ方向に駆動し、フォーカス位置の制御を行う。



【特許請求の範囲】

【請求項1】 マスクパターンを投影光学系を介して基板上に転写する投影露光装置において、前記基板の表面に所定の液体を供給する液浸装置と、前記基板の表面に前記液体を介して超音波を送出し、前記表面で反射される超音波を検出することによって前記表面の前記投影光学系の光軸方向の位置を検出する超音波方式の面位置検出装置と、を備えたことを特徴とする投影露光装置。

【請求項2】 前記基板の表面に感光材料が塗布されている際に、前記面位置検出装置は、前記感光材料の表面の前記投影光学系の光軸方向の位置を検出することを特徴とする請求項1記載の投影露光装置。

【請求項3】 前記投影光学系の前記基板側の光学素子の先端部と前記基板の表面との間を満たすように前記液体が供給されることを特徴とする請求項1、又は2記載の投影露光装置。

【請求項4】 前記液体は、水、又は有機溶媒であることを特徴とする請求項1、2、又は3記載の投影露光装置。

【請求項5】 前記基板を保持して該基板を前記投影光学系の光軸に垂直な平面上で位置決めする基板ステージと、前記面位置検出装置の検出結果に基づいて前記基板の前記投影光学系の光軸方向の位置を制御する高さ制御ステ

$$R = k_1 \cdot \lambda / NA$$

$$\delta = k_2 \cdot \lambda / NA^2$$

ここで、 λ は露光波長、 NA は投影光学系の開口数、 k_1 、 k_2 はプロセス係数である。同じ解像度を得る場合には短い波長の露光光を用いた方が大きな焦点深度を得ることができる。しかしながら、投影光学系に使用される透過性の光学部材（硝材）の分光透過特性を考慮すると、現時点ではArFエキシマレーザの193nmより短い波長の露光光を透過できると共に、比較的大きなレンズを形成できる均一な硝材はほとんどない。

【0005】

【発明が解決しようとする課題】上記の如く従来の投影露光装置（投影光学系）では、ArFエキシマレーザの193nmより短い波長の露光光を使用することは困難である。そこで、実質的に露光波長を短くする方法として、液浸法が提案されている。これは、ウエハを所定の液体中に浸し、液体中での露光光の波長が、空気中の1/n倍（nは液体の屈折率で通常1.2～1.6程度）になることを利用して解像度を向上し、焦点深度を増大するというものである。

【0006】ところで、露光時には、露光範囲全体が投

$$\begin{aligned} \text{反射率} &= \{ (1 - 1.7) / (1 + 1.7) \}^2 \times 100 \\ &= 6.7 (\%) \end{aligned}$$

空気-フォトレジスト界面では、合焦検出用の光束の比

＊ージと、を備えたことを特徴とする請求項1～4の何れか一項記載の投影露光装置。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は、例えば、半導体素子、液晶表示素子、又は薄膜磁気ヘッド等を製造するためのリソグラフィ工程に用いられる投影露光装置に関する。

【0002】

【従来の技術】半導体素子等を製造する際に、フォトリソグラフィ技術として、マスクパターンを投影光学系を介して、基板としてのレジストが塗布されたウエハ（又はガラスプレート等）上の各ショット領域に転写するステッパー型、又はステップ・アンド・スキャン方式等の投影露光装置が使用されている。

【0003】投影露光装置に備えられている投影光学系の解像度は、使用する露光波長が短く、投影光学系の開口数が多いほど高くなる。そのため、集積回路の微細化に伴い投影露光装置で使用する露光波長は年々短波長化しており、投影光学系の開口数も増大してきている。そして、現在主流の露光波長は、KrFエキシマレーザの248nmであるが、更に短波長のArFエキシマレーザの193nmの使用も検討されている。

【0004】また、露光を行う際には、解像度と同様に焦点深度も重要となる。解像度R、及び焦点深度 δ はそれぞれ以下の式で表される。

$$(1)$$

$$(2)$$

※投影光学系の焦点深度の範囲内に入る必要があるため、投影露光装置には、合焦機構（オートフォーカス機構）が設けられている。これは、一般に露光すべきウエハの表面に斜入射で光ビームを入射し、その反射光を対面の光学系で受光してウエハ表面の合焦状態を検出し、ウエハを上下に移動して合焦位置へ追い込むというものである。

【0007】露光されるウエハ表面には感光膜（フォトレジスト）が塗布されており、このフォトレジストにパターンが転写される。そこで、このフォトレジスト表面を投影光学系の焦点位置に一致させることが望ましく、フォトレジスト表面の位置を検出する必要がある。従来の投影露光装置では、ウエハが配置される空間は空気、又は窒素等の気体で満たされている。そして、例えば空気の屈折率は1であり、ウエハ表面に塗布されたフォトレジストの屈折率は、約1.7である。従って、空気-フォトレジスト界面における光の反射率は、フレネルの式より以下のように計算される。

$$(3)$$

較的多くが反射し、フォトレジスト表面の位置を検出す

ることができる。

【0008】しかし、液浸法を採用した投影露光装置の場合には、ウエハが配置される空間は液体で満たされる＊

$$\text{反射率} = \left\{ (1.3 - 1.7) / (1.3 + 1.7) \right\}^2 \times 100 \\ = 1.8 (\%)$$

水-フォトリソ界面では、空気-フォトリソ界面に比べ空間とフォトリソとの屈折率の差が著しく小さくなるため、合焦検出用の光束の反射率が低下し、フォトリソ表面の位置を正確に検出することが困難となる。

【0009】本発明は斯かる点に鑑み、露光光の波長を短波長化し、より微細なパターンを転写できる投影露光装置を提供することを目的とする。さらに、液体中で感光材料が塗布された基板上に露光が行われる場合であっても、その感光材料の表面の投影光学系の光軸方向の位置を高精度に検出することができる投影露光装置を提供することを目的とする。

【0010】

【課題を解決するための手段】本発明の投影露光装置は、マスク(R)のパターン像を投影光学系(PL)を介して基板(W)上に転写する投影露光装置において、その基板(W)の表面に所定の液体(7)を供給する液浸装置(2, 8)と、その基板(W)の表面に液体(7)を介して超音波を送出し、その表面で反射される超音波を検出することによってその表面のその投影光学系(PL)の光軸方向の位置を検出する超音波方式の面位置検出装置(5, 6)とを備えたものである。

【0011】斯かる本発明の投影露光装置によれば、マスク(R)のパターン像を液体(7)を介して基板(W)の表面に露光するため、基板表面における露光光の波長を空気中における波長の $1/n$ 倍(n は液体(7)の屈折率)に短波長化できる。また、超音波方式の面位置検出装置(5, 6)により基板(W)の表面の光軸方向の位置を高精度に検出するため、光学式の面位置検出装置では面位置の検出が困難な液体(7)中においても、その位置を高精度に検出することができる。

【0012】また、基板(W)の表面に感光材料(PR)が塗布されている際に、面位置検出装置(5, 6)は、その感光材料(PR)の表面の投影光学系(3, 4)の光軸方向の位置を検出することが望ましい。この場合、投影光学系(3, 4)の像面をその感光材料(PR)の表面に合わせ込むことができる。また、投影光学系(PL)の基板(W)側の光学素子(4)の先端部とその基板(W)の表面との間を満たすように液体(7)が供給されることが望ましい。この場合、基板(W)表面における露光光の波長を、空気中における露光光の波長の $1/n$ 倍(n は液体(7)の屈折率)に短波長化できる。さらに、投影光学系(PL)の鏡筒(3)が液体(7)に接触しないため、鏡筒(3)が腐食しにくくなるという利点がある。

＊ことになる。例えば液体が水である場合、その屈折率は1.3であり、水-フォトリソ界面における光の反射率は、フレネルの式より以下のように計算される。

(4)

【0013】また、その液体(7)は、水(屈折率1.3)、又は有機溶媒(例えばアルコール(エタノール(屈折率1.36)等)、セダー油(屈折率1.52)等)である。この場合に液体(7)として水を用いる場合には、その入手が容易であるという利点がある。また、液体(7)として有機溶媒を用いる場合には、投影光学系(PL)の鏡筒(3)が腐食しにくくなるという利点がある。さらに、液体(7)としてセダー油を用いる場合には、その屈折率が約1.5と大きく、露光光をより短波長化することができる。

【0014】また、基板(W)を保持してこの基板(W)を投影光学系(PL)の光軸に垂直な平面上で位置決めする基板ステージ(10)と、面位置検出装置(5, 6)の検出結果に基づいてその基板(W)の投影光学系の光軸方向(3, 4)の位置を制御する高さ制御ステージ(9)とを備えることが望ましい。この場合、投影光学系(3, 4)の像面に対して基板(W)の表面を高精度に合わせ込むことができる。

【0015】

【発明の実施の形態】以下、本発明の実施の形態の一例につき図1～図3を参照して説明する。図1(a)は本例の投影露光装置の概略構成を示し、この図1(a)において、露光光源としてのArFエキシマレーザ光源、オブティカル・インテグレート、視野絞り、コンデンサレンズ等を含む照明光学系1から射出された波長193nmの紫外パルス光よりなる露光光ILは、レチクルRに設けられたパターンを照明する。レチクルRのパターンは、両側(又はウエハ側に片側)テレセントリックな投影光学系PLを介して所定の投影倍率 β (β は例えば $1/4$, $1/5$ 等)でフォトリソPRが塗布されたウエハW上の露光領域に縮小投影される。なお、露光光ILとしては、KrFエキシマレーザ光(波長248nm)、F₂エキシマレーザ光(波長157nm)や水銀ランプのi線(波長365nm)等を使用してもよい。以下、投影光学系PLの光軸AXに平行にZ軸を取り、Z軸に垂直な平面内で図1(a)の紙面に垂直な方向に沿ってY軸を取り、紙面に平行な方向に沿ってX軸を取って説明する。

【0016】レチクルRはレチクルステージRST上に保持され、レチクルステージRSTにはX方向、Y方向、回転方向に微動できる機構が組み込まれている。レチクルステージRSTの2次元的位置、及び回転角はレーザ干渉計(不図示)によってリアルタイムに計測されている。一方、ウエハWはウエハホルダ(不図示)を介して試料台9上に保持され、試料台9はウエハWのフ

フォーカス位置（Z方向の位置）及び傾斜角を制御するZステージ10上に固定されている。試料台9上には円筒状の側壁8が設けられおり、その内部は液体7で満たされている。液体7は、ポンプ等からなる液体供給回収系2により、ノズル2aを介して露光前に側壁8内に供給され、露光後に回収される。なお、本例の投影露光装置では液体7として水（屈折率1.3）を使用しており、光の波長は水中において空気中の $1/1.3$ 倍になるため、ArFエキシマレーザ（波長193nm）よりなる露光光の波長は実質的に約148nmに短波長化される。

【0017】また、投影光学系PLの鏡筒3は金属製であり、液体7による腐食を防止するため、本例では、投影光学系PLと液体7との接触部分は、ウエハWに最も近いレンズ4のみとしている。また、投影光学系PLの鏡筒3の側面には、超音波射出系5と超音波受信系6とよりなる焦点位置検出系（以下「AFセンサ5、6」と呼ぶ）が取り付けられている。

【0018】図1（b）は図1（a）の側壁8近傍の拡大図であり、この図1（b）において、側壁8にはウエハWの試料台9上への搬送、又は試料台9からの搬出の際に使用する開閉自在の扉8aが設けられている。また、液体供給回収系2のノズル2aは、液体の供給、及び回収の際に上下に駆動することができる構成となっている。

【0019】図1（a）に戻り、Zステージ10は投影光学系PLの像面と平行なXY平面に沿って移動するXYステージ11上に固定され、XYステージ11は不図示のベース上に載置されている。Zステージ10は、ウエハWのフォーカス位置（Z方向の位置）、及び傾斜角を制御してウエハW上のフォトレジストPR表面をオートフォーカス方式、及びオートレベリング方式で投影光学系PLの像面に合わせ込み、XYステージ11はウエハWのX方向、及びY方向の位置合わせを行う。試料台9（ウエハW）の2次元的位置、及び回転角は、移動鏡12の位置としてレーザ干渉計13によってリアルタイムに計測されている。この計測結果に基づいて主制御系14からウエハステージ駆動系15に制御情報が送られ、Zステージ10、XYステージ11の動作が制御され、露光時にはウエハW上の各ショット領域が順次露光位置に移動し、レチクルRのパターンが各ショット領域へ露光転写される。

【0020】次に、本例の投影露光装置のAFセンサ5、6について説明する。図2（a）は、本例の投影光学系の下部近傍を拡大して示し、この図2（a）において、超音波射出系5には超音波発生素子5a、及び超音波集束素子5bが設けられている。圧電素子等からなる超音波発生素子5aから射出された周波数50MHz～200MHz程度の超音波は、超音波集束素子5bによりウエハWに塗布されたフォトレジストPR表面上の集

束位置SSに集束され、集束位置SSで反射して超音波受信系6に入射する。超音波受信系6には超音波受信素子6a、超音波集束素子6b、及び振動できる遮音板6cが設けられており、超音波受信系6に入射した超音波は超音波集束素子6bにより集束され、遮音板6cの開口を介して超音波受信素子6aに入射する。超音波受信素子6aの検出信号は主制御系14に供給される。なお、遮音板6cの中央部には超音波を通過させる開口が設けられて、主制御系14が遮音板駆動機構6dにより遮音板6cを横シフト（又は振動）させて超音波受信素子6aの検出信号が最大になる位置を検出する。又は、遮音板6cを振動させるのに同期した信号で超音波受信素子6aの検出信号を同期検波してもよい。

【0021】図2（b）は、フォトレジストPR表面上の超音波の集束位置SS付近を拡大して示し、この図2（b）において、ウエハW上には感光用のフォトレジストPRが塗布されている。従来の光学式で斜入射方式のAFセンサによりフォトレジストPR表面上の位置SSを検出しようとしても、液体7とフォトレジストPRの屈折率が同程度で反射率が極めて低くなり、光は経路17に沿ってウエハWの表面まで進むため、検出される位置SS'はフォトレジストPRの表面上に位置せず、投影光学系PLの像面にはウエハWの基板自体の表面が合わせ込まれる。本例のAFセンサ5、6の超音波は経路16に沿って進みフォトレジストPRの表面で反射されるため、フォトレジストPR表面上の位置SSが正確に検出され、高精度にフォトレジストPR表面を像面に合焦させることができる。

【0022】また、フォトレジストPR表面のZ方向の位置は、従来の光学式で斜入射方式のAFセンサと同様の原理によって超音波受信素子6a上での超音波の集束位置の横シフト量から検出される。即ち、ウエハWが図2（b）中の下方（-Z方向）にずれば図2（a）の超音波受信素子6a上での集束位置が上方にずれ、ウエハWが図2（b）中の上方にずれば超音波受信素子6a上での集束位置は下方にずれるため、この横シフト量よりフォトレジストPRの表面のフォーカス位置の変化量を求めることができる。そのため、予めベストフォーカス位置はテストプリント等によって定めておき、そのときに遮音板6cの開口の中心（又は振動中心）と超音波の集束位置の中心とを合わせておけばよい。

【0023】図3は、一例として超音波受信系6からの検出信号を同期検波して得られるフォーカス信号DとフォトレジストPR表面のフォーカス位置Zとの関係を示す。主制御系14内で、超音波受信装置6aからの検出信号を、遮音板6cの駆動信号で同期整流することによって、フォトレジストPR表面での超音波の集束位置SSに対応して、フォーカス位置Zに所定範囲でほぼ比例して変化するフォーカス信号Dが生成される。本例では、超音波の集束位置SSに対応するフォーカス信号D

は、集束位置SSが投影光学系PLの像面（ベストフォーカス位置）に合致しているときに0になるようにキャリブレーションが行われており、主制御系14は、フォーカス信号Dよりデフォーカス量（ずれ量）を求めることができる。ウエハWのフォーカス位置が上方にある場合には、Zステージ10（ウエハW）を下方に移動し、逆にフォーカス位置が下方にある場合には、Zステージ10（ウエハW）を上方に移動して露光を行うことになる。

【0024】なお、本例では液体7として水（屈折率1.3）を使用した。液体7として有機溶媒（例えばアルコール、セダー油等）を用いることもできる。この場合には、投影光学系PLの鏡筒3が腐食しにくくなるという利点がある。また、セダー油（屈折率1.5）を用いる場合には、その屈折率が1.5と大きく、露光光を実質的により短波長化することができる。

【0025】なお、フォーカス位置の検出については、超音波射出系5に複数の開口を有する遮音板を配置し、フォトレジスト表面の複数点での各フォーカス位置を検出するようにしてもよく、あるいは、大きな開口を有する遮音板を超音波射出系5内に配置し、且つ複数の開口を有する遮音板を超音波受信系6内に配置して、同様に複数点での各フォーカス位置を検出するようにしてもよい。

【0026】なお、上記の実施の形態では、超音波を用いてウエハのフォトレジスト表面のフォーカス位置を検出したが、超音波を用いてフォトレジスト表面の傾斜角を検出するレベリングセンサを用いてもよい。このレベリングセンサでは、ウエハの表面にほぼ平行に進む超音波を照射して、反射される超音波の集音位置を検出すればよい。

【0027】なお、本発明は上述の実施の形態に限定されず、本発明の要旨を逸脱しない範囲で種々の構成を取り得ることは勿論である。

【0028】

【発明の効果】本発明の投影露光装置によれば、マスクのパターン像を液体を介して基板の表面に露光するため、基板表面における露光光の波長を実質的に空気中における波長の液体の屈折率の逆数倍に短波長化できる。また、超音波方式の面位置検出装置により基板表面の光軸方向の位置を検出するため、光学式の面位置検出装置では面位置の検出が困難な液体中においても、その位置を高精度に検出することができる。

【0029】また、面位置検出装置が、感光材料の表面の投影光学系の光軸方向の位置を検出する場合には、その検出情報に基づいて投影光学系の像面に対してその感

光材料の表面を高精度に合わせ込むことができる。また、投影光学系の基板側の光学素子の先端部とその基板の表面との間を満たすように液体が供給される場合には、露光光を空気中の $1/n$ 倍（ n は液体の屈折率）に短波長化できる、また、投影光学系の鏡筒が液体に接触しないため、投影光学系の鏡筒が腐食しにくくなるという利点がある。

【0030】また、液体が、水である場合には、その入手が容易であるという利点がある。液体が、有機溶媒（例えばアルコール、セダー油等）である場合には、投影光学系の鏡筒が腐食しにくいという利点がある。さらに、液体としてセダー油を用いる場合には、その屈折率が1.5と水（屈折率1.3）等比べて大きく、露光光をより短波長化することができる。

【0031】また、基板を保持してこの基板を投影光学系の光軸に垂直な平面上で位置決めする基板ステージと、面位置検出装置の検出結果に基づいてその基板の投影光学系の光軸方向の位置を制御する高さ制御ステージとを備える場合には、投影光学系の像面を基板表面上の露光位置に合わせ込むことができる。

【図面の簡単な説明】

【図1】（a）は本発明の実施の形態の一例の投影露光装置を示す概略構成図、（b）は図1（a）の側壁8近傍を示す拡大図である。

【図2】（a）は図1（a）の投影露光装置下部の構成を示す部分拡大図、（b）は図2（a）のB部の拡大図である。

【図3】ウエハW上のフォトレジスト表面のフォーカス位置Zとフォーカス信号Dとの関係を示す図である。

【符号の説明】

W ウエハ

R レチクル

PL 投影光学系

1 照明光学系

2 液体供給回収系

3 鏡筒

4 レンズ

5 超音波射出系

6 超音波受信系

7 液体

8 側壁

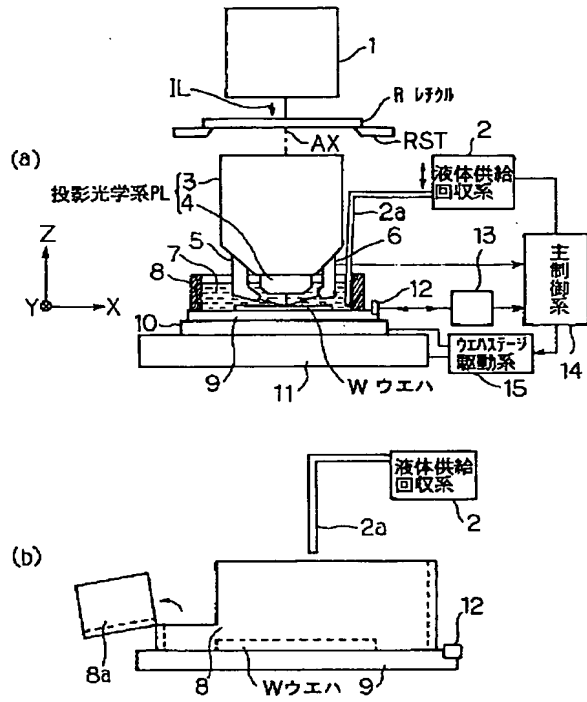
9 試料台

10 Zステージ

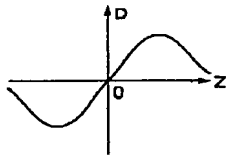
14 主制御系

15 ウエハステージ駆動系

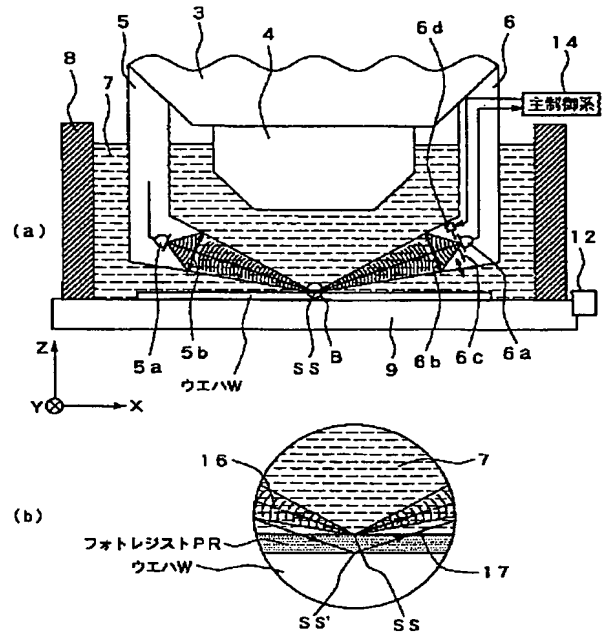
【図1】



【図3】



【図2】



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